INFLUENCE OF SUPPLY VOLTAGE ON THE VELOCITY OF FLIGHT OF DOMAINS IN A GUNN DIODE

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I. INTRODUCTION

At the present time, more and more attention is paid to modeling physical processes in semiconductor radioelements operating in the gigahertz and terahertz ranges [1, 2]. With the help of an accurate physical model, it becomes possible to predict changes in radiation characteristics due to factors such as semiconductor material, doping, supply voltage, and others.

II. RESULTS

To study the processes of formation and motion of a domain in a crystal structure, the local-field model of the Gunn diode is used, based on the assumption that the average drift velocity of electrons depends on the instantaneous value of the electric field, and the diffusion coefficient does not depend on the applied electric field [3]. A sequential circuit for switching on a diode with a power supply and a resistive load is simulated.

To describe the behavior of the domain inside the diode, the intensity formula is used in an explicit form, obtained from the Poisson equation for the field distribution:

$$E_i^{k+1} = E_i^k + \Delta t \left[D\left(E_i^k\right) \frac{E_{i+1}^k + E_{i-1}^k - 2E_i^k}{\Delta x^2} - V\left(E_i^k\right) \frac{E_{i+1}^k - E_{i-1}^k}{2\Delta x} + \right.$$

$$\left. + \frac{e}{\varepsilon_a} \left(D\left(E_i^k\right) \frac{n_{0i+1} - n_{0i-1}}{2\Delta x} - n_{0i} V\left(E_i^k\right) + \frac{U_0 - \frac{1}{2}\Delta x \sum_{j=2}^{N} \left(E_{j-1}^k + E_j^k\right)}{eRS} \right) \right], \quad (1)$$

where Δt– time interval of integration; $D\left(E_i^k\right)$– diffusion coefficient; Δx– spatial interval of integration; ε_a– absolute dielectric constant of GaAs; n_{0i}– value of the local concentration of dopants; U_0– supply voltage of the Gunn diode; N– the number of spatial intervals of the diode splitting; R – load resistance; S – cross-sectional area of the crystal structure of the diode.

The speed of electrons at adjusted point in space at a given time $V\left(E_i^k\right)$ is responsible for the nonlinear part of the device which is defined as:

$$V(E_i^k) = \frac{\left[\mu_a E_i^k + V_{\text{sat}}\left(\frac{E_i^k}{E_{\text{threshold}}}\right)^4\right]}{\left[1+\left(\frac{E_i^k}{E_{\text{threshold}}}\right)^4\right]}, \quad (2)$$

where μ_a– electron mobility; V_{sat}– the speed corresponding to the saturation of the characteristic with a large field; $E_{\text{threshold}}$ – the threshold value of the intensity in the field.

For the equation (1), the Neumann conditions for the boundaries with the diode contacts must be satisfied:

$$E_1^k = E_2^k \qquad E_N^k = E_{N-1}^k \quad (3)$$

At each time step, the field strength is found at all points in space in the diode. Thus, it becomes possible to track the movement of the intensity maxima corresponding to the strong field domain. Figure 1 shows the graphs of the intensities, which can be used to trace the dynamics of the movement of charges. The maxima located on the left side are formed by inhomogeneities, from which generation begins when the supply voltage overcomes the threshold field strength.

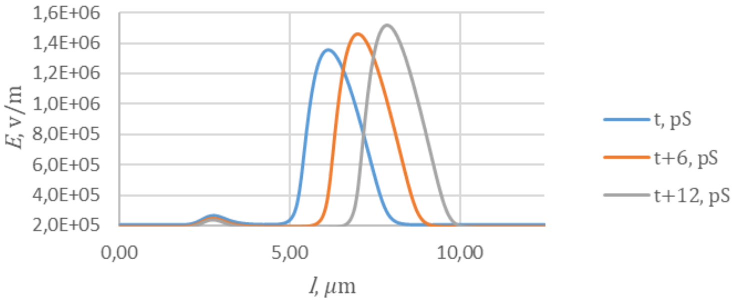

Figure 1. Change in the field strength inside the diode over time at a constant voltage U_0

The velocity of domain movement is determined by the change in the position of the tension maxima after their separation from the inhomogeneities. For various values of the supply voltage, a graph of the dependence of the speed of movement of charges on the supply voltage is obtained, shown in Figure 2.

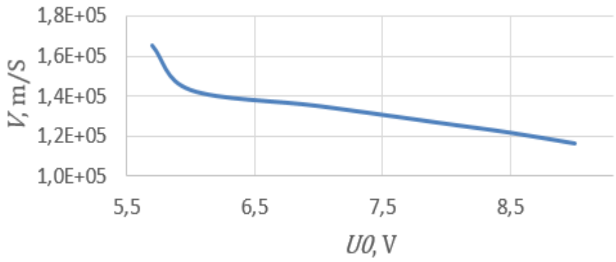

Figure 2. Change in the velocity of flight of the domain depending on the supply voltage of the Gunn diode

The resulting graph shows that with an increase in the supply voltage of the diode, the rate of movement of charges decreases. This is due to the fact that when a larger external field is applied, the Q-factor of the domain decreases, the number of main charge carriers increases, while the inhomogeneity in the diode remains constant. For the formation of a new domain, a stronger field is formed, and the effective mass increases.

III. CONCLUSIONS

The experiments carried out show that with an increase in the supply voltage, the speed of movement of the domains decreases, which coincides with the experimental characteristics of Gunn diodes operating in the sections after the nominal supply voltage on the slope of the frequency characteristics.

The shape of inhomogeneities in the crystal lattice with the same width does not affect the formation of domains. The rectangular, parabolic and gradient functions of the change in the concentration of dopants are investigated. If the function changes more smoothly, then the maximum amplitude of the domain strengths will be greater, but the domain will take a little longer to form. The resulting model can be used to calculate fields with different loads in an electrical circuit. It is planned to add an LC circuit to the circuit, which will allow calculations for different waveguides. This should make it easier to design and debug experimental circuits.

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REFERENCES

[1] Wafaa Abd El-Basit, "Computer Modeling, Characterization, and Applications of Gallium Arsenide Gunn Diodes in Radiation Environments" Nuclear Engineering and Technology, Vol. 48, Issue 5. pp 1219-1229, October 2016.

[2] Chong Li, "Design, fabrication and characterization of $In_{0.23}Ga_{0.77}As$-channel planar Gunn diodes for millimeter wave applications" Solid-State Electronics, Vol 64, Issue 1. pp 67-72, October 2011.

[3] G. I. Veselov, "Microelectronic microwave devices: a textbook for radio engineering universities" Moscow: High school, p 280, 1988.